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How can South Africa advance a new energy paradigm? A mission-oriented approach to megaprojects

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Abstract Green transition is a 'wicked' problem in that it is complex, systemic, interconnected, and urgent. In this paper we advance a 'mission-oriented' approach to reconceptualize energy megaprojects within a systemic, cross-sectoral, and challenge-driven policy framework for energy transition. This approach is operationalized through a discussion of project-level policy instruments including directional public finance, public procurement, and several types of conditionality. These instruments are geared towards shaping markets and industrial supply chains for green transition, and managing risks and rewards associated with energy megaprojects. We also look at the opportunities offered by a more decentralized energy system and the importance of building up state capacity and green coalitions supporting energy transition. We discuss this mission-oriented approach through a deep dive on the South African experience of energy megaprojects with a focus on the restructuring of its public utility, Eskom, as well as opportunities for sustainable industrialization.

Keywords: energy transition, green industrial policy, South Africa

JEL classification: H54, O14, O25, Q48, Q50

I. Introduction

Green transition is a 'wicked' problem in that it is complex, systemic, interconnected, and urgent. Several middle-income countries face the challenge of replacing carbon-intensive assets with cleaner energy infrastructure. Their energy systems have been built around large-scale investments in carbon-intensive coal-fired power plants. These

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megaprojects from the past have become increasingly unsustainable in the present—from social, economic, and environmental perspectives. They do not provide reliable and affordable electricity; they are a drain on public finance due to large cost overrun in building and management, hence the need for bailouts and permanent subsidies; and they have negative impact on climate change, local community well-being, and economic development. More critically, these megaprojects are a liability preventing a green transition into the future. Indeed, in an attempt to respond to emergency generation problems, governments have been trapped into a spiral of urgent needs and incumbents' power. Further financial resources have been committed in ineffective and highly centralized energy-system projects. In some cases, this government strategy has reinforced incumbents' interests, locked in their financial commitments, and hence increased their resistance to change.

While the cost of solar and wind energy has declined dramatically since 2009 and industrial process efficiency has increased, advancing a new energy paradigm is not simply about overcoming technological and economic constraints. It is about managing a complex structural transition involving the energy sector as much as re-directing all sectors and all actors—public, private, and civil society—towards sustainable and inclusive economic growth. In this paper, we advance a *'mission-oriented' approach* to identify and manage binding constraints in energy megaprojects, as well as seize feasible pathways for energy transition. This approach is operationalized through directional public finance, public procurement, and several types of conditionality. These instruments are all geared towards creating future markets and industrial supply chains for green transition and managing risks and rewards associated with megaprojects. Second, we identify opportunities for crowding-in investments into more distributed energy systems and the conversion of hyper-centralized legacy systems. The degree of centralization of the national energy system is critical for rethinking the governance model, restructuring energy financing, and opening the sector to new players, hence redesigning the political economy of the sector. This process includes leveraging the green transition and infrastructural momentum at the global level, ultimately pointing to multi-scalar energy-industrial policy. Finally, we look at the importance of managing conflicts and the distributional impact of energy transition by building up green coalitions supporting the implementation and enforcement of such policies.

We discuss this mission-oriented approach through a deep dive on the South African experience of energy megaprojects. South Africa is a disproportionate contributor to climate change and its power generation is largely coal based. Over the last two decades, South Africa has experienced an increasing number of megaprojects crises culminating in a perfect storm triggered by the economic and social crisis inflicted by Covid-19. South Africa is in the midst of a prolonged, multi-year, period of intermittent load shedding and unsustainable financial cost. South Africa's inability to ensure a reliable electricity supply to the economy has been a burden contributing to its low economic growth and inability to create jobs and opportunities for its citizens. The South African case is an ideal testbed for a mission-oriented green-industrial policy built around a portfolio of measures targeting different leverage points. Specifically, targeted measures could range from promoting a distributed energy system and mini-grid development via regulatory and procurement reforms, to more fundamental financial restructuring of the public utility Eskom via introduction of conditionality. Finally, linking green transition to industrial policy could result in indigenous solution-driven green innovations.

We conclude by reflecting on the implications of shifting from a market failure approach towards a more solution-driven and market-shaping mission-oriented approach for green transition. This approach promises to open space for more experimentation, targeted solutions, and more accountability in a sector traditionally vulnerable to incumbent power and rents capture.

II. Energy transition as a complex portfolio of megaprojects

Climate change is the most pressing grand challenge of the twenty-first century, perhaps the greatest, truly global challenge humankind has ever faced. Shifting away from an unsustainable energy system centred on non-renewable fossil-fuel resources is key to overcoming this global challenge. The energy sector generates around three-quarters of greenhouse gas emissions (IEA, 2021). The traditional energy system sources and centralized models have proven to be unable to provide reliable, affordable, and environmentally sustainable energy. Furthermore, there has been an increasing recognition of the fact that markets have failed to internalize environmental costs, and steer economies towards a much needed energy transition. Markets alone have also proven incapable of promoting the development and widespread diffusion of innovative green technologies for sustainable growth, hence the need for technology and green industrial policy (Mowery *et al.*, 2010; Rodrik, 2014; Penasco *et al.*, 2021).

A few countries have been experiencing transformational growth in their energy systems and infrastructure thanks to green industrial policies, including feed-in-tariffs schemes and direct public financing of energy megaprojects. Across Europe, Germany, the UK, Denmark, and Italy are perhaps the most well-known cases; China has also embarked on a dramatic energy transition (Mathews and Reinert, 2014). This 'infrastructural moment' (Bridge *et al.*, 2018), has been inspired by alternative techno-economic paradigms (Perez, 2002; Mathews, 2013). Thus far, fossil fuel decarbonization has been anchored to the mainstreaming of solar, wind, and hydro sources of energy. More recently, green hydrogen has been promoted as a way of transitioning hard-to-abate sectors. The dramatic decline in the cost of electricity from renewables since 2009—solar photovoltaics and wind, on-shore in particular—has offered a viable pathway to accelerating the energy transition. The steep learning curves associated with these technologies and their increasing installed capacity are responsible for this dramatic shift in prices. Renewable energy technologies like solar photovoltaics and wind are manufactured devices which can be produced under regimes of increasing returns (Mathews and Reinert, 2014).

In most countries, however, we have witnessed inadequate progress with the energy transition and significant resistance to shifting away from the current energy model (Arent *et al.*, 2017). This lack of progress has negatively impacted climate change mitigation globally (IEA, 2021), but also, especially among low- and middle-income countries, the energy problem is a key binding constraint to transformative development locally. The energy transition is key to unlocking inclusive and sustainable structural transformation, by promoting green industrialization, the absorption, and diffusion of new technologies, as well as for addressing social inequality. In this sense, the energy transition is a quintessentially cross-sectoral challenge, as it affects all productive, re-productive, and consumption activities in society from food and industrial production, to housing, and mobility (Sovacool and Cooper, 2013). At the same time, energy transition is also an opportunity and key leverage point for addressing inter-dependent social and economic challenges. In this sense, the energy transition configures itself as a portfolio of megaprojects.

Since Albert Hirschman's seminal work on development projects (Hirschman, 1967), the literature on megaprojects has advanced in different theoretical directions and provided several insights on challenges and fragilities arising from *within* large-scale projects (Flyvbjerg *et al.*, 2003; Flyvbjerg, 2014). Bent Flyvbjerg defines megaprojects by scale and value: 'Megaprojects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people' (Flyvbjerg, 2017, p. 3). Megaprojects are complex because they entail planning, management, and delivery along several interdependent systems and sub-systems, involving high levels of uncertainty and engaging multiple stakeholders and several multi-tiered supply chains (Ansar *et al.*, 2014; Brady and Davies, 2014; Flyvbjerg, 2017; Ansar *et al.*, 2017).

From a state capacity perspective (Kattel and Mazzucato, 2018), megaprojects' successful execution requires both ordinary and dynamic capabilities to navigate various types of task complexity, structural complexity, and directional complexity. It also requires that such dynamic capabilities are present in both business enterprises executing megaprojects, as well as public-sector institutions commissioning, financing, and regulating such megaprojects. Public-sector dynamic capabilities are, for example, central in designing procurement policies and managing risks and rewards associated with megaprojects' development. Lack of state capacity can result in perverse outcomes such as the adoption of a 'break-fix' model in megaproject management (Flyvbjerg, 2014), and the so-called 'survival of the unfittest' (Flyvbjerg, 2009). This occurs when the projects that look best on paper are also those resulting in largest cost overruns, largest overestimation of benefits, and risks of non-viability.

Energy megaprojects present further specific challenges (Sovacool and Cooper, 2013; Van de Graaf and Sovacool, 2014; Rad *et al.*, 2017; Gregory, 2020). First, the level of specialized technological capabilities involved is very high. Energy megaprojects draw on and integrate several technology modules and platforms (Brady and Davies, 2014), increasingly augmented by technology fusion into digital systems (Andreoni *et al.*, 2021*a*). Second, not only are technologies complex, but energy megaprojects also require technology adaptation to place-specific conditions. Third, while investments might be localized and commissioned by national governments, energy megaprojects are normally delivered by multinational enterprises and involve transnational collaborations and supply chains. Hence, ownership and agency are usually separated (Flyvbjerg, 2017). Fourth, especially in developing countries, the financing of these energy megaprojects relies on cross-border flows of finance and international institutional investors. Finally, energy megaprojects and the specific energy technology choice is intimately intertwined with the political economy of a country, the distribution of power, and its crystallization in institutions and regulatory frameworks. Indeed, these 'infrastructures involve diverse economies of investment, ownership, exchange and use […] (and) produce and reproduce distributional inequalities in material, and deeply spatial, ways' (Tonkiss, 2015, p. 384).

Low- and middle-income countries are particularly affected by inter-locking factors impacting megaprojects' performance and energy transition (Arent *et al.*, 2017;

Hochstetler, 2019; Lema *et al.*, 2020; Behuria, 2020; Gregory, 2020). They include path-dependence and need for dramatic investments in grid development (and maintenance); financial commitments in moving away from legacy systems and concentrated incumbent interests competing unfavourably against renewables, including lobbying to reduce the scaling up of renewables through conservative regulatory policies; lack of domestic productive and technological capabilities in renewable energy technology, hence over-reliance on foreign green technologies; and lack of state capacity and cases of state capture, especially in the presence of megaprojects. Ultimately, the distribution of political and economic power shapes the energy regulatory environment, and in doing so it can reproduce the political economy settlement in these countries (Burke and Stephens, 2018). Reversing this path-dependence can be a way to reduce power concentration and, in doing so, transitioning towards a more inclusive, distributed, and resilient energy system. Thus, transitioning away from legacy energy megaprojects is not simply about a sustainable technical transition, it is about an inclusive political transition as well (Bridge *et al.*, 2018).

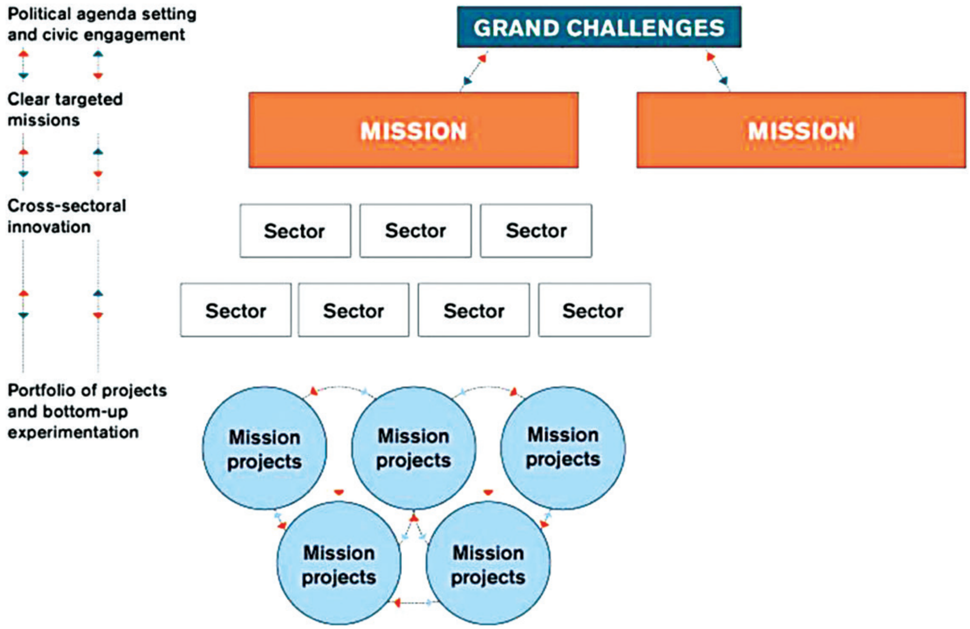
III. A mission-oriented green industrial policy approach to energy megaprojects

Several low- and middle-income countries face an energy transition deadlock because of multiple interlocking factors, especially related to their energy megaproject legacy. Escaping from this deadlock requires both restructuring existing individual megaprojects—hence applying insights from the megaprojects literature discussed above (e.g. Flyvbjerg, 2014)—as much as reframing megaprojects within a broader systemic policy perspective. A mission-oriented approach (Mazzucato, 2021) can provide such a systemic framework around which megaprojects can be restructured, re-aligned, and repurposed towards tackling major societal challenges such as climate change. Modern day mission-oriented approaches to industrial policy provide a focusing and coordinating device for multiple policy instruments and for crowding in cross-sectoral solutions—i.e. missions guide entrepreneurial self-discovery (Foray, 2018). By shaping markets and industries, mission-oriented policies can impact ways in which individual megaprojects are designed, implemented, and managed, as well as the ways in which they interact as part of an aligned portfolio of mission projects (Figure 1).

Mission-oriented challenge-driven approaches have already been employed to steer transformation in the energy sector. Germany's *Energiewende* is an interesting case of strategy bringing together multiple sectors and technologies and enabling bottom-up learning processes. Taking on missions to fight climate change, phase out nuclear power, improve energy security by substituting imported fossil fuels with renewable sources, and increasing energy efficiency, the *Energiewende* is providing a direction to technical change and growth across different sectors through targeted transformations in production, distribution, and consumption. This has allowed even a traditional sector such as steel to use the 'green' direction to renew itself through the use of a 'reuse, recycle, and repurpose' strategy.[1] This is an example of how mission-oriented policies should be

[1] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2016), *Climate Action Report 2016*, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) Public Relations Division, Berlin.

Figure 1: A mission-oriented approach to mega projects.



Source: Mazzucato, 2018*a*.

focused on ways to provide the energy sector with attractive and implementable transformation policies—fewer subsidies and more focused policies that reward investment and innovation that meet a need.

The market-shaping, mission-oriented approach to policy cuts through the problematic state–market dichotomy that dominates much discussion on economic efficiency and value, with its origins in the market failure theory and its critique. Within a market failure perspective, a minimal form of green industrial policy has been justified by two main rationales (Rodrik, 2014). The first rationale is a classical negative externality problem, according to which the full social cost of greenhouse-gas emission is not reflected by market prices. This mispricing—better, carbon under-pricing—is about markets 'misinforming' economic actors in their consumption and investment decisions. Industrial policy or simply taxes would be welcomed here to complement market signalling and reduce (ideally eliminate) this mispricing. The second rationale is related to the idea that the private return from investing in green technologies is much lower than its social return, hence there will be a situation of underinvestment that could be filled by public investments. The reason why this is the case is due to a classical positive externality and related appropriability problem. Resolving this problem poses a particular tension: restricting diffusion of technology innovation goes against the need for combatting global climate change (Mowery *et al.*, 2010).

While market failures should be corrected, a pure 'fixing' mode anchored around minimal industrial policy might not achieve the transition that is required. Indeed, making sure that new solutions (renewable energy as well as lower carbon/material content across old and new sectors) are effectively adapted, fully deployed, and diffused throughout the economy means setting a challenge-driven green industrial policy and lining up several policy instruments and megaprojects around it. Governments taking on risk-welcoming, forward-looking approaches to innovation investment is not new; it is just under-recognized. We can learn from the IT revolution in Silicon Valley, in which the state did not just 'fix', rather it took active risks, investing in all the radical technologies that fuel our smart products today: the internet, GPS, touch screen, and SIRI (Mowery *et al.*, 2010; Mazzucato, 2013, 2021; Chang and Andreoni, 2020).

Indeed, confronting the climate emergency is not just about what 'not to do' (e.g. pollute) but the new way to 'do' investment and innovation to steer growth in a green direction. It is not about more state or less state but a different type of state (Mazzucato, 2013, 2018*b*)—a state that is able to act as an investor of first resort, catalysing new types of growth, and in so doing crowd in private-sector investment and innovation which are in essence functions about expectations about future growth areas. For policy-makers, this means investments on both the supply side (*public financing*) and the demand side (*public procurement*), and along the entire innovation/production chain, from basic research to full deployment of new technologies. Various types of *conditionalities* can provide new risks–rewards arrangements functional to better performing megaprojects design and policy implementation.

The deployment of renewable technologies also opens opportunities for *decentralized energy systems* and multi-scalar policy interventions, from global financing of smart green infrastructures down to local mini-grids and technology demonstrations. An explicit *management of conflicts* arising from the distributional impact of energy transition, is finally essential to reduce incumbents from capturing or slowing the implementation and enforcement of green industrial policies. In what follows we focus on these five building blocks of a new mission-oriented green industrial policy framework geared towards energy transition.

(i) Financing and directionality

The rate of innovation is often seen as its most important characteristic. But innovation does not only have a rate—it has a direction (Mazzucato, 2018*b*). From a directionality perspective more finance is not always the solution. It is the specific *type* of finance and how it is directed towards addressing grand challenges that matter most (Mazzucato and Semieniuk, 2017, 2018). Therefore, innovation, and the finance which sits behind it, are not neutral: the provenance and characteristics of finance in innovation influence the shape and success of investments, including energy megaprojects. A green-directed transition must go beyond independent initiatives and discrete approaches and be characterized by a new lens for cross-sectoral transformative innovation. It must be underpinned by long-term, patient finance, which is willing to take risks and able to mobilize and crowd in other investors.

In this way, the climate crisis can be both a carrot and a stick to create a new direction for the global economy. Even though the cost of renewable energy has become competitive, markets will not find a green direction on their own. There is not yet a ready-made route that will make multi-directional, experimental, green innovation profitable. Only when there is a stable and consistent direction for investment, will regulation and innovation converge along a green energy transition trajectory. Business does not invest unless it sees an opportunity for growth—so turning mitigation into opportunities for investment and innovation is key.

Public financing is not simply important in terms of delivering portfolios of viable innovative solutions and crowding in private investors (Mazzucato and Penna, 2016). It is also critical in addressing problems associated with effective scaling up, deployment, and diffusion of new technologies. These are particularly challenging in economies affected by a 'middle-income technology trap' (Andreoni *et al.*, 2021*b*), that is, lack of a well-funded set of intermediate technology institutions and 'big-enough' SMEs capable of absorbing new technologies for energy transition. A combination of weak supply-push and demand-pull dynamics levels down overall levels of investments and makes gaps along the innovation and production chain even more problematic.

(ii) Public procurement, market creation, and shaping

Avoiding that innovation and investment continue along their carbon-intensive path dependence, a green industrial policy must ensure that investments into low-carbon innovation are rewarded and when markets do not exist, they are created. Governments tend to focus their attention on supply-side intervention, such as tax credit and subsidies, even when the additionality of these measures and the extent to which these types of incentives are sufficient remain unclear. Demand-side measures—especially procurement policies—can play a central role in energy transition, especially given the important role that the public sector plays in energy supply and infrastructure management. Public procurement is also central in several energy megaprojects. Governments cannot micromanage this process, as that would stifle innovation, but they can set a clear direction by creating the demand and shaping its development, make the initial high-risk bold investments which crowd in private actors later on, and reward those who are willing to invest and innovate.

Public procurement can be used to perform different functions (Edquist and Zabala-Iturriagagoitia, 2012, 2020; Lember *et al.*, 2014). First, public procurement can create (or increase) the demand for products—goods and services—as well as emerging technologies. Second, if markets do not exist, public procurement can be used to create demand and conditions for competitive processes whereby new firms emerge, and old ones are encouraged to diversify into new technology areas and markets (in some cases shifting away from their old core business). Third, public procurement can set the standards and regulatory requirements (e.g. emissions, performance targets, energy intensity) under which the products and technologies are both produced and deployed. Fourth, public procurement can be used to promote the development of a portfolio of competing products, experiment with them at different levels and in different places, and scale up those that best fit different energy system and country contexts.

(iii) Conditionalities and risks-rewards

Intrinsic to any industrial policy is the idea that compulsion mechanisms should be coupled with rewards—the so-called 'carrots and sticks'. Attaching conditionalities to policies such as financing and procurement, but also company bailouts, investment attraction schemes, business restructuring, etc. is no longer a taboo; international experiences from highly dynamic market economies are testament of *public–private conditionalities* (Mazzucato, 2021). In Germany, with the *Energiewende*, the support provided to the steel sector was conditional on the sector lowering its material content. Such conditionalities have also been important with Covid-19, so that bailouts and support to struggling sectors use the crisis as an opportunity for innovation and investment and modernization of the sectors, not just handouts. For example, Austria has responded to airline companies' bailout requests by making them conditional on climate targets. In some cases, governments have shown willingness and capabilities to go even beyond conditionalities, and rethink ownership models in view of exercising long-term strategic influence and guarantee companies' financial commitment to investment, employment retention, and restructuring. Germany and France are moving to respectively acquire or increase equity stakes in airline companies to ensure strategic infrastructural capacity.

And yet, the monopoly and/or bargaining power of major companies and sectors has allowed some of them to successfully lobby against conditionalities attached to bailout schemes. Large portions of government support are being operationalized through central bank operations, where there is often no conditionality attached. Figure 2 shows the extent to which G7 and other selected nations have used conditions in the energy sector. More than 80 per cent of the funding committed to investment in fossil fuels has no conditionality attached, and only 10 per cent of the global investments committed to the Covid-19 response benefited the 'cleanest' energies measures, like renewables or energy efficiency (Dufour *et al.*, 2021). Attaching conditionalities to bailouts and other policies is a way to steer financial resources strategically and make sure that they are retained and reinvested within productive business organizations towards socially, economically, and environmentally desirable outcomes.

Conditionalities can be used in the public–private sector interface, as discussed so far, but also at the public–public interface, both within nations and across nations. At the national level, given the cross-sectoral nature of energy transition, green industrial policy can work only if it is aligned and well-coordinated within packages of interacting measures (Andreoni and Chang, 2019). The problem of policy alignment across different policy measures and instruments is both a static and dynamic one; in fact synchronization of policies over time is critical where long-term transitions are involved. Moreover, at the implementation level, policy alignment only works if it is backed up by governance coordination among different ministries, departments, institutions, and agencies. A way of achieving this alignment and coordination is to develop public

Figure 2: Conditional and unconditional public money committed to clean, fossil fuel, and other energy in G7 nations and selected countries (right) as well as total for 2019 (left).

Source: Energy Policy Tracker, 2020.

budgeting processes that induce and incentivize policy-making beyond policy silos and around missions (Mazzucato, 2018*b*). Public–public conditionalities can in this sense play an important role, as much as private–public ones.

At the global level, public–public conditionalities can be designed in a way of directing international finance to reward certain investments more than others, while leaving developing countries sufficient policy space to implement their transition strategies. They can also be used in a reverse way to lock developed countries into committing resources towards much needed energy technology transfer. Finally, they can be used to displace domestic incumbents in the energy sector and open the sector towards more decentralized and inclusive energy systems.

(iv) Governance and decentralization

The nature of the required energy system governance arrangements is shaped by the extent to which they are designed as centralized or decentralized systems. Fossil-fuel technologies do not really offer much choice in this respect; centralization is the only way to operate energy generation, while some elements of decentralization can be introduced at the point of distribution. Renewable technologies are more flexible in this respect; indeed, they open the way to geographically distributed energy sources and technology mixes, from generation to distribution and storage. For this reason, they can also lead to a more distributed energy governance system and more distributed political and economic power (Burke and Stephens, 2018).

In general, wind and solar photovoltaics energy technologies are more flexible and energy generation can range from very small 1 kW generators up to 100MW or larger facilities. By connecting to the distribution or sub-transmission sections of the energy grid infrastructure, they also enable a reduction in the distance between energy generation and load. Integrating renewables into the main grid requires investments in the physical infrastructure and storage facilities, and the introduction of new operational models, especially smart energy demand–response management. Integrating distributed, but variable generation sources can actually increase system reliability, but may require investment in extra-long-distance transmission and digital technologies. In terms of investment and ownership, solar allows for greater decentralization than wind.

With the introduction of renewable technologies, however, new systems are needed for the governance and control of the energy grid infrastructure. Micro-grids and distributed storage facilities come to the fore in this respect, as they allow the modularizing of the overall energy infrastructure by creating interconnected loads and distributed generation and storage resources in a specific place. This could be a local community, a special industrial zone, a port, etc. This form of modularity brings more resilience to the overall system, but also allows for new governance models of demand–supply and risks–rewards. Reaching optimal level of economies of scale means considering all these different factors in the definition of the degree of centralization in a specific regional and country context.

(v) Conflicts management and green coalitions building

The choice of different technologies and their governance models create potential winners and losers in the short run, even when in the long run everyone (including future generations) will benefit from sustainable energy transition. How long the short run is and how much energy transition has distributional consequences among groups, places, and countries, makes energy transition highly political. Notwithstanding, the management of conflicting claims in energy transition and more broadly in industrial policy-making is often considered as an aside and *ex post* problem (Andreoni and Chang, 2019). This despite the fact that the history of successful industrial policy-making has been about promoting change, as much as making sure that those that are potentially going to lose are given an exit option and are steered towards their restructuring and transformation. Government institutions are themselves expressing different interests, partially reflecting the broader political economy context in which they operate. Therefore, as much as managing conflicting interests among groups (and sub-groups) within the broader society, governments will face the challenge of managing conflicts within themselves.

While *prima facie* the energy transition should have a clear supporting constituency, the slow progress in implementation of green policies and regulations suggests that constituencies are also fragmented in space and time, hence the need to build green coalitions along different dimensions (Roberts *et al.*, 2018). Several analyses of climate policies in China, India, Brazil, and South Africa have pointed out how most stakeholders supporting energy transition have in fact multiple, sometimes conflicting, objectives including energy security, building competitive green industries, creating jobs, or ensuring future public revenue (Arent *et al.*, 2017; Hochstetler, 2019). Understanding how coalitions against energy transitions are formed, how they leverage financing and capabilities, is also critical to unlocking green transition and transforming incumbents.

IV. From power crisis to green transition in South Africa: case study

South Africa's energy system is at a critical crossroads. South Africa's inability to ensure a reliable electricity supply to the economy has been a key binding constraint to its structural transformation (Andreoni *et al.*, 2021*b*). South Africa's electricity crisis contributed directly to the country's pre-Covid-19 economic recession (Oqubay *et al.*, 2022). In 2021, as the country emerged from the most intense levels of the Covid-19 lock-down phases, the electricity shortage placed a hard constraint on the potential for economic recovery. In what follows we analyse the South African context and the government's policy responses through the mission-oriented industrial policy approach introduced above.

(i) The legacy of energy megaprojects in South Africa

South Africa's electricity sector structure is from a bygone era when the pursuit of ever larger economies of scale in coal-fired power generation required the establishment of a large monopoly (Eskom) in an attempt to reduce the cost of funding its ever-growing power station megaprojects (Table 2). By the 1980s it became clear that this industry model had become dysfunctional by leading to increasingly unmanageable mega-projects, with large cost and time overruns (Steyn, 2006). After electricity shortages in the late 2000s induced a decision to build two further large, coal-powered stations—called Medupi and Kusile—significant cost and time overruns exposed South Africa to a second, larger, wave of mega-project crises (Gregory, 2020). The monopoly approach to power supply creates many perverse managerial incentives; leaves the scope for innovation in the hands of a few; and enables large-scale rent-seeking behaviour in Eskom and for its suppliers of coal fuel, technology, capital goods, services, and labour—all riding on the monopoly platform.

The impact of these interlocking factors ultimately manifests as a failure by the sector to achieve its primary objectives: suppling citizens and the economy with energy security in the form of clean, reliable, and affordable electricity, and to do so without placing a burden on the sovereign finances. The sharp edge of this failure manifests as increasing load shedding—where large geographic areas of electricity demand are shed on a systematic and rotational basis—and urgent demands for significant fiscal bailouts—all of which comes at an enormous economic cost. South Africa is confronted with the reality that it faces a prolonged, possibly multi-year, period of intermittent load shedding. A recent study found that 2021 has been South Africa's worst year to date for load-shedding[2] with between 1,700 GWh and 1,800 GWh worth of load shedding, over 1,099 hours, in the year to mid-November. Without any interventions to accelerate current electricity sector investment plans, load-shedding is expected to persist and possibly worsen until at least 2025, with a capacity supply gap ranging between 5,000 MW and 8,000 MW.[3]

Given South Africa's dramatic reliance on coal-fired power plants—over 80 per cent of energy generation in 2020 (Eskom, 2021*c*)—and the age of Eskom's coal-fired power plants (Table 2), the expense of maintaining such plants and the cost of coal supplies, it is increasingly uneconomic to refurbish many of these stations compared to the new lower cost options available (Wright *et al.*, 2017). Eskom's high debt level and poor financial position further constrains the public utility's ability to run an effective refurbishment and maintenance programme to restore the available plant capacity required to meet demand. Furthermore, this over-dependence on coal means that South Africa is a disproportionate contributor to climate change. Global coal use in electricity generation will have to be drastically reduced to avoid the worst impacts of climate change. The world economic system is responding to this unprecedented crisis, with financial markets and regulators moving to restrict the financing of coal-based economic activity. South Africa's policy commitment to decarbonization (South African Government, 2021) adds a new dynamic of risks and opportunities to the restructuring of Eskom and the wider economy—including a COP26-linked offer of concessional climate finance, from the UK, USA, Germany, France, and the EU, to assist the country's transition to a lower-carbon electricity system.

An accelerated electricity sector transition is the key to South Africa's sustained economic recovery. Specifically, several coal-fired power stations which are at the end of their lives can now be replaced by an energy mix including megaprojects in renewable

[2] *Engineering News*, 8 November 2021, https://www.engineeringnews.co.za/article/with-south-africa-set-to-breach-1-000-hours-of-load-shedding-in-2021-concerns-grow-about-maintenance-finance-and-skills-2021-11-08

[3] This estimated supply gap is conservative as it assumes that South Africa's chief electricity investment planning instrument—the Integrated Resource Plan (IRP 2019)—will be executed timeously.

Table 1: Comparative costs of building new generation capacity

Technology	Levelized cost of energy	Capital cost	Build time	Eskom position
PV solar	4.1 US$c/kWh	825 US$/kW	18 to 24 months	Identified potential sites to retrofit PV to capitalize on existing infrastructure and available resources
Wind	5.4 US$c/kWh	1,450 US$/kW	24 to 36 months	Leverage sites for wind, with environmental authorizations to capitalize on existing infrastructure and available resources
Gas	7.3 US$c/kWh	1,250 US$/kW	24 to 60 months	Intend to use gas as means to enable renewables, thereby supporting the transition
Nuclear	19.8 US$c/kWh	12,500 US$/kW	12 to 15 years	Supports governments plans to roll out nuclear, will be unable to build due to inadequate balance sheet
New coal	15.9 US$c/kWh	62,250 US$/kW	10 to 12 years	Will own and operate current coal fleet till end of life, will focus on repurposing sites to be decommissioned with renewables. No new coal projects by Eskom

Source: Eskom (2021*a*, p. 5).

energy sources. As Table 1 indicates, Eskom has identified, that as at 2021, photovoltaic solar energy and wind energy produce electricity at lower cost—and can be deployed more rapidly—than gas, nuclear, and coal energy power plants. Solar and wind prices continue to fall with the latest round of successful bidders announced in October 2021 to build over 2,500 MW of new solar and wind capacity in the next 36 months offering prices of less than 4 US$c/kWh.[4]

(ii) A mission approach to energy megaprojects restructuring for green transition in South Africa

The South African government has embarked on a set of governance and regulatory reforms aimed at accelerating the transition towards a more decentralized, sustainable, and reliable energy system. A more fundamental restructuring of the main public utility Eskom owning over 90 per cent of the energy megaprojects is also under way (Eskom, 2021*c*). Eskom poses several risks to the South African economy[5] and will need to be

[4] *Engineering News*, 12 November 2021, https://www.engineeringnews.co.za/article/mantashe-announces-well-priced-round-five-renewables-projects-ending-long-hiatus-2021-11-12

[5] The risks posed by Eskom can be characterized as follows: operational risk—load shedding has devastating impacts on GDP and jobs, and is an investment disabler; financial risk—Eskom's revenues are not sufficient to cover minimum capex, opex, and debt service costs; the entity cannot finance the necessary capital expenditure to restore its electricity availability factor (EAF) and expand the grid; and the raising of tariffs to the levels that would be required to generate sufficient revenue will reduce demand, resulting in what is termed a 'utility death spiral'; debt risk—Eskom's debt burden is unsustainable with the state as the ultimate guarantor, impacting negatively on the state's balance sheet and credit rating; and climate risk—impending international carbon border tax adjustments will undermine the competitiveness of South Africa's exports if Eskom's emission intensity is not addressed, and carbon intensity is becoming a barrier to investment.

Table 2: Energy mega-projects in South Africa, 1960–2021

Name of station by energy megaproject type	Location (province)	Years commissioned, first to last unit	Number and installed capacity of generator sets, MW	Total installed capacity, MW	Total nominal capacity, MW
BASE-LOAD STATIONS					
Coal-fired power (15)				**43,256**	**38,773**
Hendrina	Middelburg (Mpumalanga)	May 1970 to Dec 1976	6x200; 2x195; 1x170	1,760	1,135
Arnot	Middelburg (Mpumalanga)	Sep 1971 to Aug 1975	6x370	2,220	2,100
Kriel	Bethal (Mpumalanga)	May 1976 to Mar 1979	6x500	3,000	2,850
Matla	Bethal (Mpumalanga)	Sep 1979 to Jul 1983	6x600	3,600	3,450
Duvha	Emalahleni (Mpumalanga)	Aug 1980 to Feb 1984	5x600	3,000	2,875
Lethabo	Vereeniging (Gauteng)	Dec 1985 to Dec 1990	6x618	3,708	3,558
Tutuka	Standerton (Mpumalanga)	Jun 1985 to Jun 1990	6x609	3,654	3,510
Matimba	Lephalale (Limpopo)	Dec 1987 to Oct 1991	6x665	3,990	3,690
Kendal	Emalahleni (Mpumalanga)	Oct 1988 to Dec 1992	6x686	4,116	3,840
Majuba	Volksrust (Mpumalanga)	Apr 1996 to Apr 2001	3x657; 3x713	4,110	3,843
Camden	Ermelo (Mpumalanga)	Mar 2005 to Jun 2008 (originally between 1967 and1979)	3x200; 1x196; 2x195; 1x190; 1x185	1,561	1,481
Grootvlei	Balfour (Mpumalanga)	Apr 2008 to Mar 2011 (originally between 1969 and1977)	4x200; 2x190	1,180	570
Komati	Middelburg (Mpumalanga)	Mar 2009 to Oct 2013 (originally between 1961 and1966)	4x100; 4x125; 1x90	990	114
Medupi	Lephalale (Limpopo)	Aug 2015 to Nov 2019	5x794	3,970	3,597
		Under construction	1x794		
Kusile	Ogies (Mpumalanga)	Aug 2017 to Mar 2021	3x799	2,397	2,160
		Under construction	3x800		
Nuclear (1)				**1,940**	**1,860**
Koeberg	Cape Town (Western Cape)	Jul 1984 to Nov 1985	2x970	1,940	1,860
PEAKING STATIONS					
Gas/liquid fuel turbine (4)				**2,426**	**2,409**
Acacia	Cape Town (Western Cape)	May 1976 to Jul 1976	3x57	171	171
Port Rex	East London (Eastern Cape)	Sep 1976 to Oct 1976	3x57	171	171
Ankerlig	Atlantis (Western Cape)	Mar 2007 to Mar 2009	4x149.2; 5x148.3	1,338	1,327

Table 2: Continued

Name of station by energy megaproject type	Location (province)	Years commissioned, first to last unit	Number and installed capacity of generator sets, MW	Total installed capacity, MW	Total nominal capacity, MW
Gourikwa	Mossel Bay (Western Cape)	Jul 2007 to Nov 2008	5x149.2	746	740
Pumped storage schemes (3)				**2,732**	**2,724**
Drakensberg	Bergville (KwaZulu-Natal)	Jun 1981 to Apr 1982	4x250	1,000	1,000
Ingula	Ladysmith (KwaZulu-Natal/ Free State)	Jun 2016 to Feb 2017	4x333	1,332	1,324
Palmiet	Grabouw (Western Cape)	Apr 1988 to May 1988	2x200	400	400
Hydroelectric stations (2)				**600**	**600**
Gariep	Norvalspont (Northern Cape)	Sep 1971 to Mar 1976	4x90	360	360
Vanderkloof	Petrusville (Northern Cape)	Jan 1977 to Feb 1977	2x120	240	240
RENEWABLE ENERGY					
Wind energy (1)				100	100
Other hydroelectric (4)				61	
Total Eskom-owned capacity (30)				**51,115**	**46,466**
Independent Power Producers (IPP)					**6,083**
Concentrating solar power					500
Gas/liquid fuel					1,005
Hydroelectric					18
Landfill					8
Solar PV energy					2,157
Wind					2,395

Note: The difference between installed and nominal capacity reflects auxiliary power consumption and reduced capacity caused by the age of the plant.
Source: Authors based on Eskom (2021*c*).

restructured and revitalized to play a leading role in the energy transition. This restructuring is mainly relying on a financing mechanism, including the use of various types of conditionalities. The success of these reforms depends on the development of a coalition supporting and mainstreaming the energy transition within a broader mission-oriented cross-sectoral agenda for structural transformation.

The broad outlines of this strategy have already been set out in the latest update of the Integrated Resource Plan (IRP) in 2019, which sees the bulk of new power coming from wind and solar resources combined with complementary technologies (gas, battery storage, etc.) to maintain security of supply. Specifically, the IRP 2019 states that:

'The development of generation for own use must also be encouraged through the enactment of policies and regulations that eliminate red tape without compromising security of supply.' In mid-2021, the building of new electricity generation capacity has been given a boost by regulatory reforms that cut red tape for private investment in electricity generation projects of up to 100MW. It is expected that the 2021 reforms will result in a step-change and that significantly more investment in privately owned electricity capacity will be initiated by this policy shift. The desire for lower costs and rapid deployment is expected to favour wind and solar investments which will take place on the balance sheets of private-sector entities, and which will mostly not be constrained by delays in government planning. It is also expected that the regulations will allow firms to sell excess power to unrelated parties and to 'wheel' excess electricity across the grid at a fee.

However, the new regulatory framework raises a series of related questions which will need to be dealt with, including grid management, given the multiplicity of electricity producers that will be allowed to wheel power over the grid, the putting in place of new fee structures for grid operators to charge for grid usage and grid connections, new financing models for municipalities that hitherto have relied on electricity tariffs to cross-subsidize other activities, and also the restructuring of Eskom so that *inter alia* an effective new publicly owned grid operating company can be created to manage grid expansion, grid maintenance, and grid usage.

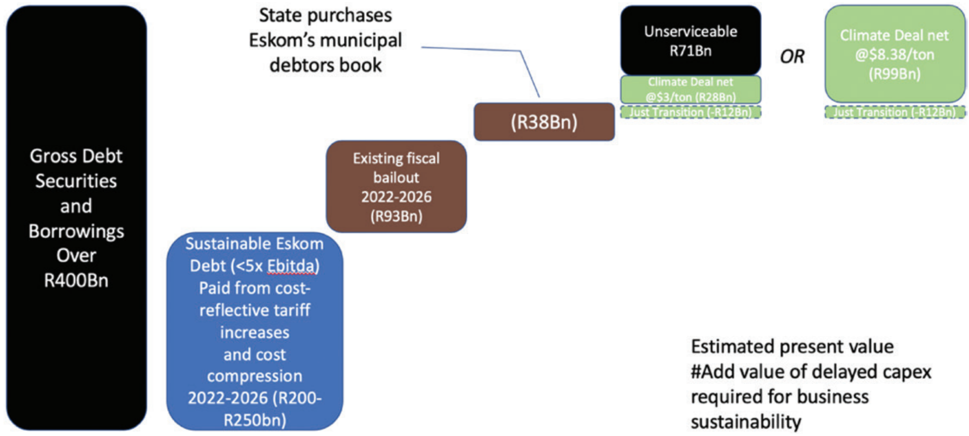
Despite delays in implementing the IRP2019, and government's shorter-term emergency procurement process,[6] utility-scale investments in renewable energy are slowly getting under way, with 25 new wind and solar projects having been announced in October 2021 and with more such announcements expected in 2022. After competitive bidding processes managed by the Department of Mineral Resources and Energy (DMRE)'s IPP Office, Eskom—or a future central entity following the restructuring of Eskom—will procure this additional electricity via purchasing power agreements and will pass on the costs of such electricity to consumers.

In 2021, Eskom's debt stood at around R400 billion and Eskom receives transfers from the South African government to assist the entity to continue as a going concern. In FY2021 government transferred R56 billion to Eskom, with transfers expected of between R23 billion and R32 billion per year from FY2022 to FY2026. Government transfers are mainly used to service Eskom's interest payments and support the repayment of maturing debt. Eskom's current debt level is unsustainable, in that ongoing high-interest payment obligations undermine the liquidity and financial viability of the entity. It has been submitted by Eskom management that a sustainable debt level would need to be less than 3.25 times the entity's earnings before interest, taxes, depreciation, and amortization (EBITDA), which is estimated as a debt of about R200–R250 billion, on condition that cost-reflective tariffs are implemented and the rising municipal debt problem can be addressed.

As per Figure 3, to achieve such a sustainable debt level, Eskom's current debt would have to be reduced by about R150–R200 billion. There are several strategies which

[6] The emergency procurement process known as the 'risk mitigation independent power procurement programme' (RMIPPP) that was put in place in addition to IRP 2019, in the wake of increasing load-shedding, has been mired in delays and court challenges due to allegations by losing bidders of improprieties in the procurement process.

Figure 3: Components of a sustainable debt solution for Eskom.



Source: Meridian Economics.

should be considered with the aim of assisting in reducing the debt on Eskom's balance sheet by R150–R200 billion and with the aim of reducing debt repayment costs. First, it may be possible to implement a policy of reducing Eskom's debt by seeing to it that the South African government assumes the refinancing of Eskom's maturing debt. Second, effective interest costs could be reduced through accessing concessional Green Finance, linked to the meeting of de-carbonization obligations. This is dependent on the carbon mitigation targets South Africa is prepared to commit to and the achievement of those targets. Third, the National Treasury may be able to take over the overdue municipal debt of some R38 billion from Eskom's books, with appropriate mechanisms to prevent moral hazard and with the proviso that, in the event of non-payment, Eskom will have step-in rights to act as the defaulting municipality's agent to operate its distribution network and collect revenue to ensure the current Eskom account is serviced.

Subject to public–public restructuring and decarbonization conditions, part of the debt on Eskom's balance sheet could over time effectively be moved to the South African national government through a process whereby, as about R200 billion of Eskom debt matures over the next 5 years, it is refinanced by the South African government. In effect, at the time of refinancing, South African's national government will borrow the money needed by Eskom and transfer the money to Eskom. In accessing climate finance, two-way public–public conditionalities could be applied to ensure, first, that South Africa and Eskom's access to grants and concessional finance is conditional on achieving certain decarbonization, restructuring, and just energy transition objectives and, second, that developed countries agree to technology transfers and localization conditions in order to assist South Africa in advancing its just transition and industrial policy objectives. This would include the following parties:

- the South African Government and Eskom commit to delivering substantial, additional CO_2 reductions;
- development finance institutions, multilateral development banks, climate funds, capital markets, etc. provide large-scale concessional funding and agree to technology transfer or localization conditions; and

- labour and affected communities benefit from a Just Transition programme (backed by the net proceeds from the transaction) and crowding in of green industrialization and a sustained large renewable energy programme.

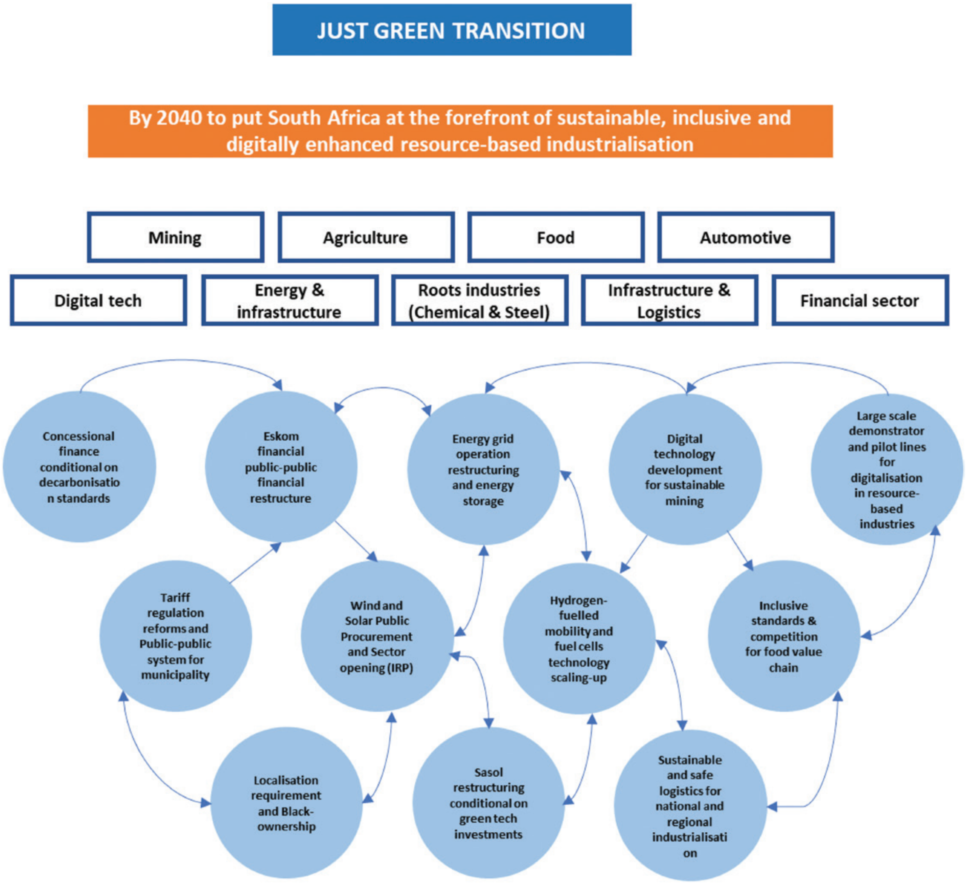
Following on from its financial restructuring, Eskom will need to be unbundled into separate generation transmission and distribution entities, with the transmission entity to play a strategic role in expanding and managing the national electricity grid. The grid needs to be extended into new areas where new generation capacity can tap into the best wind and solar resources, mainly in the Northern Cape, Eastern Cape, and Western Cape provinces. Historically, the grid has been based around the country's coal fields, mainly in Mpumalanga province (Figure 3). Beyond the reconfiguration of the country's electricity grid, Eskom's so-called 4-D challenge include the 'decarbonization' of its electricity generation profile through developing renewable energy and energy storage projects; the adoption of 'digital' technologies to optimize operations, improve grid management, and implement smart metering; facilitating 'decentralized' electricity markets as more homes and firms engage in self-generation; and allowing for 'democratization' where customers have a choice of service providers and can play the role of both producers and consumers of electricity (Eskom, 2021*b*).

Despite the decentralized nature of technologies being introduced through the energy transition, it is vital to the successful execution of the transition that the state and state-owned utility Eskom have the requisite capacity to manage and guide the various complex and overlapping elements of the transition. Given the country's history of corruption and the related weakening of state capacity (Andreoni *et al.*, 2021*b*), the carrying out of interventions to strengthen this capacity is an important precondition for the success of the energy transition project. The areas where renewed emphasis on state capacity is required include the effective and timely implementation of the country's Integrated Resources Plan (IRP)—the country's key electricity investment planning instrument, which should be incrementally and regularly recalibrated and updated, given changing technology costs and changing supply and demand patterns. Relatedly, the procurement process flowing from the IRP should continue to be executed with a high degree of autonomy by the Independent Power Procurement Office (IPP Office). A modernized and updated electricity regulatory framework for the purpose of guiding the energy transition will need to be developed and run under the auspices of the National Energy Regulator of South Africa (Nersa). For example, updated regulations are required to provide for 'wheeling' tariffs as independent power producers 'wheel' electricity across the national grid.

From a mission-oriented perspective, to conceive of the solution to South Africa's energy crisis as simply 'fixing Eskom' is to misdiagnose the problem and to overlook the immense opportunities for climate change mission-driven cross-sectoral transformation of the economy (Andreoni *et al.*, 2021*b*). By integrating the expansion in renewable energy generation capacity with active industrial policy measures, significant potential exists for accelerating growth, investment, and employment opportunities. Among the many cross-sectoral measures and megaprojects that could be implemented to achieve this mission, two are particularly relevant given the South African context (Figure 4).

Local ownership, including specified ownership by black South Africans, of renewable energy megaprojects could be enhanced by well-conceived localization requirements. Errors should be avoided where unrealistic early-stage localization requirements slow down the pace of electricity investment resulting in continued electricity shortages and

Figure 4: A mission-oriented approach to green transition for South Africa.



Source: The authors.

significant resultant losses for the economy. It is imperative that policy 'noise' and uncertainty related to South Africa's roll-out of renewable energy capacity be reduced by iteratively updating and recalibrating the IRP and implementing public procurement accordingly. Policy uncertainties, and stop-start episodes, dramatically reduce the localization potential of the programme. For example, the decision by Eskom to refrain from signing power purchase agreements for renewable-energy projects procured in 2015 resulted in some of the manufacturing capacity that had been developed around the renewable energy programme being closed, including a wind tower manufacturing plant in the Eastern Cape province and a solar PV manufacturing plant in KwaZulu-Natal province.

In the longer run, the fact that South Africa has world-class solar and wind potential[7] means that the shift towards increased solar PV and wind power has the

[7] Wind Atlas South Africa and Solar Radiation Data referenced in the Wind and Solar PV Resource Aggregation Study for South Africa undertaken by the CSIR, SANEDI, and Fraunhofer IWES, March 2016 https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf

potential to reduce the rate of electricity price increases and over time restore international competitiveness for the South Africa's energy-intensive economy. This would confer a fundamental advantage to the South African economy in exporting low-carbon, electricity-intensive, hydrogen-rich products—including 'green' products, such as, 'green' aviation fuel, 'green' steel, and 'green' fertilizers and chemicals. South Africa has an enormous green hydrogen market opportunity, which will require a drastic increase in the size of the power sector. South Africa is ideally placed to export green hydrogen and the development of the green hydrogen economy will assist South Africa in decarbonizing hard-to-abate sectors locally and abroad.

South Africa's energy transition process is highly contested. Vested interests that accrue rent from the current structure of energy production stand in the way of South Africa adopting policies which will move the economy onto a more inclusive, more dynamic growth path. Vested interests are typically backward looking and have the potential to lock the economy onto an uncompetitive path, not just because they eschew low-cost energy technologies, but also because, due to climate change, high-carbon energy technologies are increasingly difficult to finance and may pose barriers to exports. As part of the process to overcome resistance to the transition, affected workers and communities will need specific support measures to present them with viable pathways to future economic activity, via retraining and re-skilling, as well as the location, where feasible, of renewable energy projects in coal-producing areas to keep up economic activity and employment in those areas.

V. Concluding remarks

The twenty-first century is increasingly being defined by the need to respond to major social, environmental, and economic challenges. Sometimes referred to as 'grand challenges', these include climate change, demographic challenges, and promotion of health and wellbeing. Behind these challenges lie the difficulties of generating sustainable and inclusive growth. Growth has not only a rate, but also a direction: and green growth is about debating how to redirect growth in sustainable ways while at the same time increasing investment, jobs, and innovation. Green growth is a 'wicked' problem. It is also an opportunity to confront the inter-linked structural problems facing the South African economy: lagging investment in business, inertial bureaucracy in government, rising inequality, and a lack of trust in government's ability to do anything about it.

In this context the role of the public sector is to set a direction for change, and use every instrument possible—from procurement to grants and loans—to crowd in solutions by different types of organizations. Key here is the notion of transformation—all sectors from low-tech ones to the emerging high-tech ones and in both manufacturing and services, can become part of the solution. But this requires a new form of collaboration between the state and business. This includes redesigning public–private partnerships to be less about subsidies, guarantees, and handouts and more about conditionalities linked to governing a system that produces dynamism aimed at publicly set goals.

New forms of collaboration must be about market shaping, not market fixing. Yet market failure approaches are prominent in the green transition. For decades, environmental, social, and governance issues, and the metrics around them, have been siloed into market-fixing concepts such 'negative externalities'. Yet while positive externalities can justify the investment in basic research, and negative externalities the design of carbon taxes, what is required for a green transition is a clear remit to actively shape and co-create markets, not only fix them. Through well-defined goals, or more specifically what we define as 'missions', that are focused on solving important societal challenges, policy-makers have the opportunity to determine the *direction* of growth by making strategic investments, coordinating actions across many different sectors, and nurturing new industrial landscapes that the private sector can develop further. A mission-oriented approach provides a key coordination and systemic device to repurpose energy megaprojects.

The result would be an increase in cross-sectoral learning and macroeconomic stability. This 'mission-oriented' approach to green industrial policy is not about top-down planning by an overbearing state; it is about providing a direction for growth, increasing business expectations about future growth areas, and catalysing activity—learning within and across firms that otherwise would not happen. It is not about de-risking and levelling the playing field, nor about supporting more competitive sectors over less, since 'the market does not always know best', rather it is about tilting the playing field in the direction of the desired societal goals, such as the Sustainable Development Goals (SDGs).

In South Africa, energy strategy should be incorporated at the heart of the national industrial strategy. The industrial strategy needs to move away from being—as it has been and remains in many countries—an inflexible list of high-performing sectors and towards missions on renewables and development of innovative industrial ecosystems. From the point of view of Eskom, taking on a mission-oriented approach means addressing structural and operational inefficiencies in a manner which catalyses long-term green action in the private, public, and civil sectors.

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